

PID with Fuzzy Logic Adaptive Control—The Best of Both Worlds



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Proportional integral derivative (PID) control is a well-established way of driving a system towards a target position or level. It's practically ubiquitous as a means of controlling temperature, and finds application in myriad chemical and scientific processes as well as automation. PID control is however not without problems. It can yield less than ideal results in situations where the target value changes, whether as a step function or as part of a "ramp & soak" profile.

In an effort to improve performance, some instrumentation manufacturers are exploring the value of using "fuzzy logic" for process control. This OMEGA Engineering White Paper explores both the weaknesses of PID systems and the potential benefits of fuzzy logic, with particular reference to issues in temperature control. Individual sections address:

- Basics of PID control loops
- PID challenges
- Introduction to fuzzy logic for control
- PID plus adaptive fuzzy logic
- Applications

BASICS OF PID CONTROL LOOPS

In the most basic form of control loop feedback, an output such as temperature is measured and compared to a target value.

Based on the difference between these values a correction factor is calculated and applied to the input. If an oven is cooler than required, the heat will be increased. In proportional control, (the first term in the PID acronym) the correction factor is proportional to the difference. In consequence, the target value is never achieved because as the difference approaches zero, so too does the applied correction.

Integral action, the second term in "PID", attempts to remedy this. It effectively cumulates the error result from the "P" action, using this to increase the correction factor. If the oven remained below temperature "I" would act to increase the heat delivered. However, rather than stop heating when the target is reached, "I" attempts to drive the cumulative error to zero, resulting in an overshoot.

The third letter, D for derivative, attempts to minimize this overshoot. It does this by slowing the correction factor applied as the target is approached.

PID CHALLENGES

The mathematics in a PID control equation is complex with multiple variables and constants interacting. In any given application these are selected to follow the target value as closely as possible, within the constraints imposed by the process itself and the instrumentation.



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Three issues common to almost every process control application are:

- Time delays or lag
- Step function response
- “Ramp & Soak” function response

In many situations the output can take a long, and perhaps also variable, time to react to input changes. To give one example, a furnace will cool when “charged” with new metal and could take several minutes to come back up to temperature. This can lead to temperature overshoots which may damage the contents. Alternatively, the heating may be too slow, reducing process efficiency and causing deleterious effects to the product or material.

When the target value changes instantaneously PID forces the system to apply a large correcting factor, which again can lead to overshoot. Alternatively, the system may become saturated, unable to supply sufficient correction, adding to the impact of the “I” term.

These problems also occur in “ramp & soak” situations where temperature is increased gradually then held. Tracking a gradual change in setpoint can challenge PID control systems.

As a result, selecting the optimal values is something of a trial-and-error process known as “tuning.” Over the years many approaches to tuning have been developed, the most satisfactory of which appears to be the “Ziegler Nichols” method. However, this produces high levels of oscillation, which can be problematic in some situations.

INTRODUCTION TO FUZZY LOGIC FOR CONTROL

Conventional computing is based on Boolean logic, meaning everything is represented as either zero or one. In some situations this leads to oversimplification and inadequate results. Fuzzy logic, and by extension, fuzzy control, seeks to deal with complexity by creating heuristics that align more closely with human perception of problems.

Fuzzy logic provides a way of dealing with imprecision and nonlinearity in complex control situations. Inputs are passed to an “inference engine” where human or experienced-based rules are applied to produce an output.

PID PLUS ADAPTIVE FUZZY LOGIC

Tuning of PID loops depends on heuristics yet often ends up being sub-optimal. Fuzzy logic provides an alternative to approaches such as Ziegler Nichols, and a growing body of research suggests it yields superior results. Thus it would seem an ideal way to control many complex processes is with a PID controller tuned with fuzzy logic.

One commercially available product incorporating such an approach is the OMEGA® Platinum Series of temperature and process controllers. This family of compact microprocessor-based PID controllers, available in three DIN sizes, is designed to be easy to set-up and use. All common thermocouples and RTDs can be connected, with the system automatically enabling only the relevant functions for the input type selected. Voltage and current inputs are also available, allowing use with almost any engineering units. These controllers provide a complete PID solution, supporting complex programs with up to 16 Ramp & Soak sequences. Auto tune is available for PID applications with adaptive fuzzy logic to help attain optimal results.

APPLICATIONS

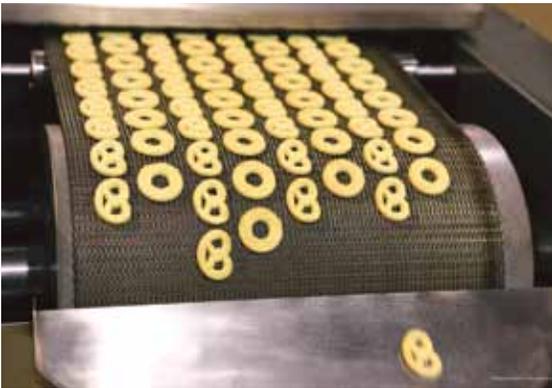
Unless open-loop control is acceptable, almost every process control application would benefit from PID control. In terms of temperature control, good examples are:

- Heat treatment of metals. “Ramp & Soak” sequences need precise control to ensure desired metallurgical properties are achieved.



Heat treatment of metals.

- Drying/evaporating solvents from painted surfaces. Over-temperature conditions can damage substrates while low temperatures can result in product damage and poor appearance.
- Curing rubber. Precise temperature control ensures complete cure is achieved without adversely affecting material properties.
- Baking. Commercial ovens must follow tightly prescribed heating and cooling sequences to ensure the necessary reactions take place.



Commercial baking facility.

- Ceramics. Continuous kilns must deliver high levels of heat yet are subject to varying thermal loads. This makes them an ideal application for PID control.

In addition, many scientific and chemical processes rely on careful and accurate control of temperature.

KEY TAKEAWAYS

Closed-loop control attempts to keep the actual output from a process as close to the target or setpoint output as possible.

PID control is an established method of providing such control, but requires tuning for optimal performance. Such tuning is complex and difficult so heuristic techniques, such as the Ziegler Nichols method, are usually employed.

Processes requiring step change or “Ramp & Soak” control are especially difficult to handle through conventional PID techniques. To address this, controller manufacturers like OMEGA are incorporating fuzzy logic-based auto tuning capabilities. Advanced computational techniques are used to help optimize PID loops, and provide improved levels of process control.

Source

Understanding Derivative in PID Control
<http://www.controleng.com/search/search-single-display/understanding-derivative-in-pid-control/4ea87c406e.html>

Fixing PID
<http://www.controleng.com/search/search-single-display/fixing-pid/3975ca-d3f121d8df3fc0fd67660822b1.html>

Fixing PID, Part 2
<http://www.controleng.com/search/search-single-display/fixing-pid-part-2/0e4d8566095ee71883b2bc3026bd02d7.html>

The Three Faces of PID
<http://www.controleng.com/search/search-single-display/the-three-faces-of-pid/d07e7664bd3c50f3621ff9c63c24a91e.html>

<http://www.mathworks.com/help/fuzzy/what-is-fuzzy-logic.html> “fuzzy logic ... can be a very powerful tool for dealing quickly and efficiently with imprecision and nonlinearity.”

Fuzzy Control
<http://www2.ece.ohio-state.edu/~passino/FCbook.pdf>

http://inside.mines.edu/~msimoes/documents/Intro_Fuzzy_Logic.pdf

Understanding Setpoint Ramping and Ramp/Soak Temperature Control
<http://blog.west-cs.com/blog/understanding-setpoint-ramping-and-ramp-soak-temperature-control>

<http://blog.west-cs.com/blog/programmable-temperature-controllers>

What is PID Control?
<http://blog.west-cs.com/blog/what-is-pid-control>

What Is PID Tuning & How Does It Work?
<http://blog.west-cs.com/blog/what-is-pid-tuning-how-does-it-work->

<http://www.slideshare.net/literaturedevourer/pid-controller-tuning-using-fuzzy-logic>

AUTOMATIC TUNING OF PID CONTROLLER USING FUZZY LOGIC
<http://www.dasconference.ro/papers/2006/B8b.pdf>

Comparative Analysis of Tuning a PID Controller using Intelligent Methods
http://www.uni-obuda.hu/journal/Chopra_Singla_Dewan_54.pdf